THE EUTROPHIC STATUS OF TEN CENTRAL IOWA LAKES

An abstract of a Thesis by
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The problem. To date little work has been done determining the eutrophic status of small central Iowa lakes. The purpose of this study is to (1) determine the eutrophic status of ten central Iowa lakes; (2) compare and contrast any differences between the lakes located within the Wisconsin Glacial drift and those lakes located outside of this area; and (3) compare and contrast any differences between natural and man-make lakes.

Procedure. During the spring of 1975, the fall of 1975 and the spring of 1976, composite water samples were taken from the euphotic layer of each lake. Each water sample was then subjected to various tests including: alkalinity, free carbon dioxide, specific conductance, pH, nitrate and nitrite nitrogen and ortho and meta phosphate. After autoclaving, each water sample was innoculated with a test algae, Selenastrum capricornutum, and incubated under set conditions. Cell counts and algal dry weights were determined. The algal dry weights and seasonal changes in lake alkalinity were correlated to the eutrophic status of each lake.

Findings. After incubation, all the samples from the man-made lakes had moderate algal dry weight values while the algal dry weight values of the samples from the natural lakes were higher. In general, the lakes located within the Wisconsin Glacial drift had higher chemical parameters than those located outside of this area but this did not seem to have any effect on the general eutrophic status of any lake studied.

Conclusion. Of the lakes studied the man-made lakes are mesotrophic while the natural lakes are eutrophic.

Recommendations. It is suggested that further studies on these lakes be more quantitative, employing more frequent samplings and including nutrient budgets and turnover to aid in developing a plan to improve water quality.

THE EUTROPHIC STATUS OF TEN CENTRAL IOWA LAKES

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INTRODUCTION

The terms eutrophic and oligotrophic were first used by C. A. Weber (1907, cited by Hutchinson, 1973) to describe the different stages of bog succession. E. Naumann (1919, cited by Wetzel, 1975) used these terms to describe different water types that he classified according to the concentration of nitrogen and phosphorus present. Characterization of these terms was expanded to the present day definitions when it was found that midge larvae, mostly of the genus Tanytarus, were characteristic of oligotrophic or unproductive, deep lakes in which the hypolimnion retained high levels of oxygen during summer stratification (Thienemann, 1925, cited by Wetzel, 1975). By contrast, eutrophic lakes were shallower, richer in phytoplankton production, had lower oxygen concentrations in their hypolimnion and were thus dominated by species that could tolerate lower oxygen concentrations.

Eutrophication is the process by which the above mentioned changes occur. It is a natural aging process that proceeds at a different rate in each lake. Recently nitrogen and phosphorus have been implicated as the major nutrients in accelerating the process of eutrophication (Sawyer, 1966; Vollenwieder, 1968; Weiss, 1969; Shindler et al., 1971). Other nutrients are also required, however, and elements such as iron, zinc, molybdenum and manganese can also stimulate phytoplankton production (Gerloff and Skoog, 1957; Miller and Tash, 1966; Goldmann, 1967; Koelling, 1971).

Algal bioassays were developed outside of the United States as a means of testing the ability of freshwater to support algal growth (Lund et al., 1971; Forsberg, 1972). Methods, however, were improvised to meet specific needs and thus offered no basis for comparison. This deficiency was recognized in the United States and researchers began solving specific problems associated with previous methods. Some of these problems included: (1) formulation of a culture medium that minimized intracellular nutrient carryover in the innoculum; (2) determination of the optimum age of the innoculum; (3) determination of the optimum sample surface area to volume ratio in the test container; (4) determination of the best physical parameters for growth; and (5) determination of the best methods to use to measure algal biomass. After these problems were solved, the National Eutrophication Research Program published the Provisional Algal Assay Procedure, Bottle Test (Bartsch, 1971). This procedure was later evaluated by different laboratories using the same source of samples (Weiss and Helmes, 1971) and the results of the tests proved to be excellent.

Algal assays have now been recognized as an easier, quicker means of testing the ability of water to support algal growth than the usual standard chemical analysis

(Cullimore and McCann, 1972; Cain and Trainor, 1973). It has also proved very successful in testing for the limiting nutrients of an aquatic ecosystem (Denison, 1974), studying the effects of nutrient addition (Cullimore and McCann, 1972; Ferris et al., 1974; Miller et al., 1975) and determining the eutrophic state of lakes and ponds (Miller et al., 1974; Chiaudani and Vighi, 1974). In eutrophication studies that use algal bioassays, four productivity groups can be defined based on the algal dry weights of eight day old cultures (Miller et al., 1974):

Low productivity 0.00-0.10 mg/l oligotrophic
Moderate productivity 0.11-0.80 mg/l mesotrophic
Moderately high prod. 0.81-6.00 mg/l meso-eutrophic
High productivity 6.10-20.00 mg/l eutrophic, hypereutrophic

Other methods used to determine the eutrophic status of a lake include changes in the epilimnetic alkalinity values during the summer (Vollenweider, 1968).

Ultra-oligotrophic < 0.2 meq/l or < 10 mg $CaCO_3$/l
Oligo-mesotrophic 0.2-0.6 meq/l or 11-30 mg $CaCO_3$/l
Meso-eutrophic 0.6-1.0 meq/l or 31-50 mg $CaCO_3$/l
Eutrophic, hyper-eutr. > 1.0 meq/l or > 50 mg $CaCO_3$/l

To date little work has been done on central Iowa lakes although some chemical parameters have been determined (Bachmann, 1965) and high inputs of phosphorus have been correlated to algal blooms in the Iowa "Great Lakes"

(Bachmann and Jones, 1975). The purpose of this study is to:

(1) determine the eutrophic status of ten central Iowa lakes using algal dry weights and seasonal changes in the epilimnetic alkalinity values of each lake

(2) compare and contrast any differences in lakes located in and outside the limits of the Wisconsin Glacial Drift

(3) compare and contrast any differences between natural and manmade lakes.

MATERIALS AND METHODS

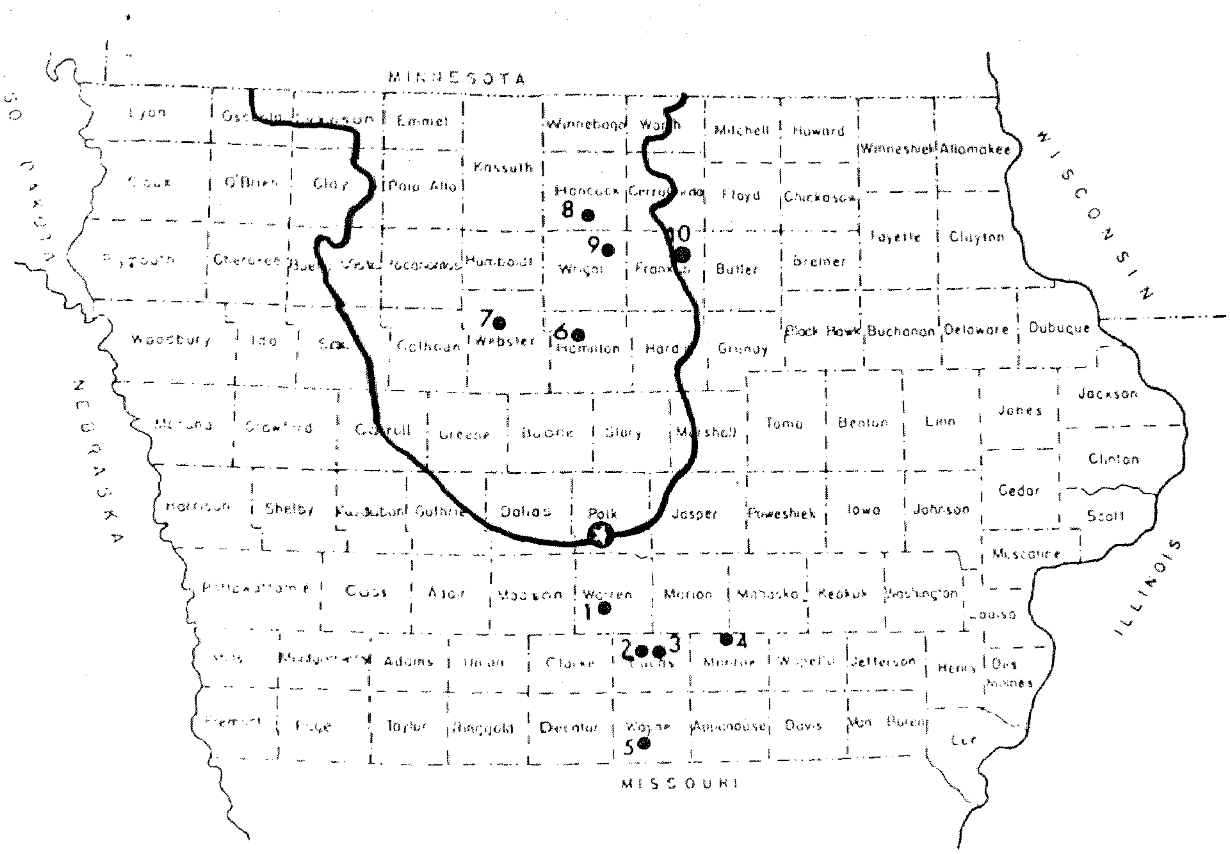
The Lakes

Ten Iowa lakes were selected for sampling based on their location and surface area. Five of the lakes (#1-#5) are situated south of Des Moines, while the remainder (#6-#10) are located north of Des Moines. Lakes #6-#9 are located within the Wisconsin Glacial Drift and generally have higher water chemical parameters than those located outside of this area (Bachmann, 1965). More information on the lakes is contained in Table 1 and Figure 1.

The sampling site chosen was the approximate center of each lake so that a representative sample could be obtained. Composite water samples were obtained from the euphotic layer of each lake with a non-metalic 3.1 liter Kemmerer water sampler. The depth of the euphotic layer was

Table 1. Type, location, surface area, and date of construction of each lake.

Lake	Manmade (M) or Natural (N)	County	Surface Area (Acres)	Date Constructed
1) Ahquabi	M	Warren	130	1935
2) Ellis	M	Lucas	110	1916
3) Red Haw	M	Lucas	83	1935
4) Miami	M	Monroe	142	1966
5) Bob White	M	Wayne	115	1913
6) Briggs Woods	M	Hamilton	70	1968
7) Badger	M	Webster	60	1962
8) West Twin	N	Hancock	109	---
9) Morse	N	Wright	108	---
10) Beeds	M	Franklin	130	1936



LAKES SOUTH

1 AHQUABI

2 ELLIS

3 RED HAW

4 MIAMI

5 BOB WHITE

LAKES NORTH

6 BRIGGS WOODS

7 BADGER

8 WEST TWIN

9 MORSE

10 BEEDS

Figure 1. Location of lakes and of the Wisconsin glacial drift. One inch equals approximately 59 miles (Bachmann, 1965).

roughly estimated to be slightly more than the Secchi disk readings. Samples were taken from each lake in the Spring of 1975, in the Fall of 1975 and in the Spring of 1976. The five lakes of each group were normally sampled within a two day time period and the sampling of each group was conducted on consecutive weekends with the group of southern lakes being sampled first.

Chemical-physical Methods

Field analyses. Secchi disk readings and water temperatures were taken during the sample collection. The water used for the chemical analysis was obtained from the same composite sample used for the algal bioassay. The following analyses were performed: alkalinity (Welch, 1948), free carbon dioxide (Welch, 1948), specific conductance and pH. A Beckmann Solu Bridge, with reference temperature of 25°C, was used to determine specific conductance and pH was determined using the Hach Chemical Company's Bromo-thymol blue test kit, model #17-f. All of these analyses were done immediately after collection of the water sample.

Lab analyses. Tests performed in the laboratory included: ortho and meta phosphate (Stannous chloride method, American Public Health Association, 1975), nitrate nitrogen (Nitra-Ver IV method, Hach Chemical Co.), and nitrite nitrogen (Nitri-Ver method, Hach Chemical Co.). The water used for the above tests were taken from the autoclaved prepared water samples used for the algal bioassay. Nitrate and phosphate analysis was conducted within 72 hours to prevent any change in the water samples using a Hach Chemical Company DR-A colorimeter with the appropriate filter.

Bioassay Methods

Bioassay methods are based on the Algal Assay Procedure (Bartsch, 1971) established by the National Eutrophication Research Program. The water samples were stored in the dark in glass containers and on ice until transported back to the laboratory. The water samples were then prepared by autoclaving at 121°C and 15 p.s.i. for thirty minutes to solubilize any nutrients contained in filterable organisms and detritus. Since free carbon dioxide gas is lost during this process causing an increase in the pH, the samples were allowed to cool and equilibriate in the open air back to their original pH level. They were then passed through a 0.45 micron membrane filter and stored in the dark at 0-4°C until needed.

Selenastrum capricornutum, (Printz) was selected as the test algae and a culture (No. 1648) obtained from the collection at Indiana University. This culture was innoculated into the nutrient broth recommended in the Algal Assay Procedure (Bartsch, 1971). It was incubated in a Lab Line Biotronette Plant Growth Chamber, model #845, at 24 ± 2°C under cool-white fluorescent lighting of 400 foot-candles (4304 lux) ± 10%. Due to equipment limitation the lighting had a cycle of 22 hours of light and 2 hours of dark. After twelve days the innoculum was prepared by centrifuging the algae at 1000 X g, discarding the supernatant and washing the algal cells in glass-distilled water containing 15 mg $NaHCO_3$ per liter. The algae were then recentrifuged, the supernatant discarded, and resuspended in more of the water-bicarbonate solution.

As each lake assay was done in triplicate, thirty 250 ml flasks were used as culture vessels. Seventy milliliters of the prepared test water was pipetted into the flasks and enough innoculum added to obtain a final concentration of 10^3 cells per milliliter. These cultures were incubated under the conditions previously described.

Cell counts were made daily by using a Spencer Bright-Line Improved Neubauer Hemocytometer. Two fields were counted and averaged and only cells in the four corner grids and the center grid were counted. Cells on the top and bottom of the boundaries of the grid were counted while cells on the lateral boundaries of each grid were not.

After eight days dry weights were determined by filtering a measured amount of the test culture through a tared type AA Millipore 0.8 micron filter, dried in an oven at 90°C and cooled overnight in a desiccator and reweighed.

RESULTS

Chemical-physical Results

Secchi disk readings varied between lakes and with time. Values (Table 2) ranged from a low of 18 cm (Morse Lake, Fall, 1975) to a high of 140 cm (Lake Ahquabi, Spring, 1976).

Nitrate and nitrite nitrogen values (Table 3) ranged from 0 to 20 mg/l and 0.003 to 0.056 mg/l respectively. With both nutrients, the southern lakes (#1-#5) had lower values than the northern lakes (#6-#10).

Orthophosphate values (Table 3) ranged from 0.15-0.75 mg/l. In all but one case, the values found in the Spring of 1976 were either equal to or exceeded those found in the Spring of 1975. In general, the northern lakes had higher values (0.15-0.50 mg/l) than the southern lakes (0.15-0.25 mg/l). With the exception of Lake Ahquabi, and its values, metaphosphate values (Table 3) showed seasonal variation with somewhat lower values being found in the fall than in the spring.

The hydrogen ion concentration (pH) varied from 7.4 to 9.2 and again values in all lakes were slightly higher in the Spring of 1976 than in the Spring of 1975 (Table 4). In seven out of ten lakes, the values found in the Fall of 1975 were also slightly higher than those found in the Spring of 1975.

Table 2. Sampling time, sky conditions, Secchi disk readings, and water temperature per sampling period per lake.

Lake	Time of Day	Sky Conditions	Secchi disk (cm)	Water Temp. (°C)
1) Ahquabi				
4/11/75	9:00 am	Partly Cloudy	50	4.0
9/12/75	8:00 am	Cloudy	45	16.0
4/2/76	7:30 am	Clear	140	7.5
2) Ellis				
4/11/75	11:00 am	Clear	130	4.5
9/12/75	9:45 am	Cloudy	52	17.0
4/2/76	9:00 am	Clear	75	9.5
3) Red Haw				
4/11/75	12:15 pm	Clear	100	6.0
9/12/75	12:15 pm	Clear	100	16.0
4/2/76	10:00 am	Clear	100	13.5
4) Miami				
4/11/75	5:00 pm	Partly Cloudy	40	4.0
9/12/75	5:20 pm	Partly Cloudy	40	18.0
4/2/76	4:00 pm	Clear	50	12.0
5) Bob White				
4/11/75	2:30 pm	Partly Cloudy	47	10.0
9/12/75	3:00 pm	Partly Cloudy	40	17.0
4/2/76	12:15 pm	Clear	20	8.5

Table 2. Continued.

Lake	Time of Day	Sky Conditions	Secchi disk (cm)	Water Temp. (°C)
6) Briggs Woods				
4/18/75	10:30 am	Overcast, rainy	60	7.0
9/19/75	10:00 am	Scattered Clouds	65	19.0
4/9/76	9:00 am	Clear	55	9.0
7) Badger				
4/18/75	12:45 pm	Overcast, rainy	20	9.5
9/19/75	12:15 pm	Scattered Clouds	50	19.0
4/9/76	10:45 am	Clear	50	10.0
8) West Twin				
4/18/75	3:15 pm	Overcast, rainy	36	8.0
9/19/75	4:00 pm	Scattered Clouds	24	17.0
4/9/76	1:20 pm	Clear	30	10.0
9) Morse				
4/19/75	11:00 am	Overcast	25	5.5
9/20/75	1:15 pm	Overcast	18	15.0
4/10/76	2:30 pm	Partly Cloudy	25	11.0
10) Beeds				
4/19/75	1:35 pm	Overcast	45	5.0
9/20/75	5:00 pm	Cloudy	80	18.0
4/10/76	6:00 pm	Partly Cloudy	50	10.0

Table 3. Nitrate nitrogen, nitrite nitrogen, orthophosphate and meta-phosphate values per lake at each sampling period.

Lake	Nitrate nitrogen (mg/l)	Nitrite nitrogen (mg/l)	Orthophosphate (mg/l)	Metaphosphate (mg/l)
1) Ahquabi				
Spring 75	6.0	0.040	0.65	0.06
Fall 75	6.0	0.031	0.60	0.05
Spring 76	7.0	0.050	0.75	0.10
2) Ellis				
Spring 75	0.0	0.035	0.21	0.09
Fall 75	2.0	0.028	0.25	0.09
Spring 76	3.0	0.047	0.25	0.11
3) Red Haw				
Spring 75	0.0	0.010	0.19	0.11
Fall 75	2.0	0.010	0.15	0.08
Spring 76	2.0	0.010	0.20	0.05
4) Miami				
Spring 75	0.0	0.015	0.20	0.15
Fall 75	0.0	0.015	0.20	0.12
Spring 76	2.0	0.015	0.20	0.12
5) Bob White				
Spring 75	0.0	0.030	0.18	0.11
Fall 75	0.0	0.020	0.18	0.10
Spring 76	2.0	0.022	0.18	0.15

Table 3. Continued.

Lake	Nitrate nitrogen (mg/l)	Nitrite nitrogen (mg/l)	Orthophosphate (mg/l)	Metaphosphate (mg/l)
6) Briggs Woods				
Spring 75	20.0	0.040	0.45	0.10
Fall 75	10.0	0.040	0.50	0.10
Spring 76	20.0	0.035	0.50	0.10
7) Badger				
Spring 75	18.0	0.055	0.15	0.15
Fall 75	11.0	0.049	0.45	0.10
Spring 76	14.0	0.056	0.40	0.12
8) West Twin				
Spring 75	9.0	0.010	0.25	0.09
Fall 75	7.0	0.015	0.25	0.08
Spring 76	9.0	0.008	0.35	0.05
9) Morse				
Spring 75	0.0	0.005	0.35	0.09
Fall 75	2.0	0.003	0.30	0.05
Spring 76	4.0	0.008	0.30	0.18
10) Beeds				
Spring 75	12.0	0.080	0.15	0.07
Fall 75	9.0	0.047	0.20	0.05
Spring 76	12.0	0.029	0.25	0.09

Table 4. pH, free carbon dioxide, alkalinity and specific conductance values per lake at each sampling period.

Lake	pH	Free CO_2 (mg/l)	Alkalinity (mg $CaCO_3$/l)	Specific Conductance (micromho/cm)
1) Ahquabi				
Spring 75	7.4	4.0	90	230
Fall 75	7.5	2.5	117	260
Spring 76	8.5	0.0	75	285
2) Ellis				
Spring 75	7.7	7.0	101	320
Fall 75	8.0	5.0	121	260
Spring 76	8.9	0.0	100	305
3) Red Haw				
Spring 75	7.4	4.0	91	240
Fall 75	7.7	3.0	115	220
Spring 76	8.7	0.0	87	240
4) Miami				
Spring 75	7.4	4.0	87	300
Fall 75	9.2	0.0	119	320
Spring 76	8.2	2.0	95	320
5) Bob White				
Spring 75	7.8	2.0	78	280
Fall 75	7.7	3.0	105	285
Spring 76	8.3	1.0	85	290

Table 4. Continued.

Lake	pH	Free CO_2 (mg/l)[2]	Alkalinity (mg $CaCO_3$/l)	Specific Conductance (micromho/cm)
6) Briggs Woods				
Spring 75	7.8	7.0	265	625
Fall 75	8.5	0.0	160	445
Spring 76	9.2	0.0	149	500
7) Badger				
Spring 75	7.9	5.0	222	630
Fall 75	9.0	0.0	200	420
Spring 76	9.2	0.0	162	620
8) West Twin				
Spring 75	8.7	0.0	180	348
Fall 75	9.0	0.0	85	300
Spring 76	8.8	0.0	129	340
9) Morse				
Spring 75	8.3	1.0	131	320
Fall 75	8.4	0.0	86	240
Spring 76	8.5	1.0	118	340
10) Beeds				
Spring 75	7.8	1.0	233	550
Fall 75	8.3	0.0	200	420
Spring 76	8.0	3.0	146	490

The amount of free carbon dioxide gas (Table 4) varied, as expected, with the pH and ranged from 0 to 7 mg/l. Alkalinity (Table 4) was measured as mg of calcium carbonate per liter and ranged from 75 to 265 mg/l. Alkalinity values for the northern lakes were higher than the southern lakes. In lakes (#1-#5), Fall 1975 values were lower than Spring 1975.

The specific conductance values (Table 4) of the northern lakes (#6-#10) reached a high of 630 micromhos/cm while the two natural lakes were lower. Lowest values were found in the southern lakes, the lowest being 220 microhos/cm.

Bioassay Results

The average cell counts (Table 5) after eight days of incubation ranged from a low of 8.17 X 10^3 cells/ml (Briggs Woods Lake, Spring, 1976) to a high of 32.5 X 10^3 cells/ml (Morse Lake, Spring, 1976). The southern lakes consistently had higher cell counts (17,000 cells/ml) than their northern counterparts (13,500 cells/ml), but the two natural lakes had the highest cell counts of all (34,000 cells/ml). Individual cell count data is given in the Appendix Tables 8 to 10.

The dry weights (Table 6) had a high of 1.40 mg/l (Morse Lake, Spring, 1976) and a low of 0.35 mg/l. The two natural lakes had the highest values (Spring, 1976) and showed the greatest amount of change during the study (10,500-23,000 cells/ml).

Table 5. Cell number (1×10^3 cells/ml) and standard deviation (1×10^3) per lake at each sampling period.

Lake	Spring 75	Fall 75	Spring 76
1) Ahquabi	12.50 ± 0.50	13.17 ± 0.14	15.50 ± 0.50
2) Ellis	12.00 ± 0.00	11.25 ± 1.89	12.92 ± 0.38
3) Red Haw	8.75 ± 0.50	8.67 ± 0.76	10.83 ± 1.89
4) Miami	10.67 ± 1.15	10.83 ± 0.29	9.83 ± 2.02
5) Bob White	16.50 ± 0.50	16.83 ± 0.29	15.67 ± 1.15
6) Briggs Woods	9.17 ± 0.29	8.92 ± 0.38	8.17 ± 0.14
7) Badger	10.33 ± 1.62	10.67 ± 0.29	10.53 ± 0.38
8) West Twin	11.17 ± 0.58	21.33 ± 0.29	22.50 ± 1.32
9) Morse	26.08 ± 1.80	29.00 ± 1.15	32.50 ± 1.32
10) Beeds	11.17 ± 1.04	12.08 ± 0.14	13.00 ± 0.66

Table 6. Dry weight (mg/l) values per lake at each sampling period, and lake averages.

Lake	Spring 75	Fall 75	Spring 76	X ± S.D.
1) Ahquabi	0.70	0.53	0.70	0.64 ± 0.10
2) Ellis	0.53	0.53	0.53	0.53 ± 0.00
3) Red Haw	0.35	0.35	0.53	0.41 ± 0.10
4) Miami	0.53	0.35	0.35	0.41 ± 0.10
5) Bob White	0.53	0.53	0.70	0.59 ± 0.10
6) Briggs Woods	0.53	0.35	0.35	0.41 ± 0.10
7) Badger	0.53	0.53	0.53	0.53 ± 0.00
8) West Twin	0.53	0.88	1.23	0.88 ± 0.35
9) Morse	0.88	1.05	1.40	1.11 ± 0.27
10) Beeds	0.53	0.35	0.53	0.47 ± 0.10

DISCUSSION

A students "t" test comparing the average cell counts of the northern manmade lakes to the southern manmade lakes showed that there was a significant difference between these two groups of lakes, with the southern group of lakes being more productive. These calculations gave a "t" value of 3.94 which is significant at the 99% level. Another "t" test comparing cell counts of the northern manmade lakes with the northern natural lakes gave a "t" value of 1.43 which is below the level of 95% significance.

The Southern Lakes

All of the algal dry weights of the southern lakes fit into the moderate productivity range (mesotrophic) of 0.11-0.80 mg/l (Miller et al., 1974), with Lake Ahquabi having the highest dry weight followed by Bob White, Ellis, Miami and Red Haw. Ortho and metaphosphate values were high and were similar in all lake samples except in Lake Ahquabi where orthophosphate values were extremely high averaging 0.66 mg/l. Lake Ahquabi also had the highest nitrate and nitrite values of any lake in this group. The changes in alkalinity values in the epilimnion during the summer are all in the mesotrophic range (Vollenwieder, 1968) of approximately 0.4-0.8 meq/l or 20-40 mg $CaCO_3$ /l.

The Northern Manmade Lakes

All of the algal dry weights for these lakes also fit into the moderate productivity range (mesotrophic) of 0.11-0.80 mg/l (Miller et al., 1974) with Badger Lake having the highest dry weight, followed by Beeds and Briggs Woods. Metaphosphate values for these lakes are similar to those found in the southern lakes. Orthophosphate values in Briggs Woods or Badger are higher than those found in all of the southern lakes with the exception of Lake Ahquabi, while the values found in Beeds Lake are about the same as those found in the remainder of the southern lakes. Nitrate, nitrite and specific conductance values are also higher in these northern lakes than those found in the south. These higher chemical parameters did not have a great effect on the general eutrophic status of these lakes.

The changes in alkalinity values in the epilimnion during the summer are also in the mesotrophic range of 0.4-0.8 meq/l or 20-40 mg $CaCO_3$/l for both Badger and Beeds Lake. Briggs Woods Lake is in the hypereutrophic range of > 50 mg $CaCO_3$/l, but this status is not reflected either in the cell counts or in the algal dry weights so something in that system appears to be limiting potential algal production.

The Northern Natural Lakes

Both of these lakes, Morse and West Twin, had the highest algal dry weights and cell counts of all the lakes that were sampled even though orthophosphate, nitrate and nitrite values were lower than those of the other northern lakes. The algal dry weights of these lakes fit into the moderately high productivity range of 0.81-6.00 mg/l (Miller et al., 1974). The changes in values of alkalinity in the summer also fit into the eutrophic range of 0.8 meq/l or 40 mg $CaCO_3$/l (Vollenwieder, 1968). Thus both of these lakes can be considered eutrophic. A summary of lake classification can be found in Table 7.

Regression analyses were used to attempt to correlate the different concentration of phosphates and nitrates present in each lake sample to the average cell number in each lake sample after eight days of incubation, but no significant correlations were found. Regression analysis did show, however, a significant negative correlation between nitrite concentration and cell number. This implies that a toxicity factor could be present. More experimental work must be done to establish this, however, as that type of problem is beyond the scope of this particular study.

For further studies of these lakes it is recommended that more samples be taken throughout the Spring and Summer in an attempt to quantify each lake ecosystem. Also analysis of nutrient budgets, turnover and immobilization in the sediments could be examined, all of these would aid in developing plans to improve the water quality of these lakes.

This study has determined that: (1) all eight of the

Table 7. Lake classification by dry weight values (mg/l) and changes in epilimnetic alkalinity values (mg/l) during the summer.

Lake	Average Dry Weight	Classification by Dry Weight	Changes in Alkalinity	Classification by Changes in Alkalinity	Final Classification
1) Ahquabi	0.64	mesotrophic	27	oligo-mesotrophic	mesotrophic
2) Ellis	0.53	mesotrophic	20	oligo-mesotrophic	mesotrophic
3) Red Haw	0.41	mesotrophic	24	oligo-mesotrophic	mesotrophic
4) Miami	0.41	mesotrophic	32	meso-eutrophic	mesotrophic
5) Bob White	0.59	mesotrophic	27	oligo-mesotrophic	mesotrophic
6) Briggs Woods	0.41	mesotrophic	105	eutrophic	mesotrophic
7) Badger	0.53	mesotrophic	22	oligo-mesotrophic	mesotrophic
8) West Twin	0.88	meso-eutrophic	95	eutrophic	eutrophic
9) Morse	1.11	meso-eutrophic	45	meso-eutrophic	eutrophic
10) Beeds	0.47	mesotrophic	33	meso-eutrophic	mesotrophic

manmade lakes studied are mesotrophic while the two natural lakes are eutrophic; (2) the lakes located within the Wisconsin Glacial Drift have higher alkalinity and specific conductance values than those outside of this area; (3) although there is a statistical difference in cell counts between northern manmade and southern manmade lakes, it is not large enough to affect the lakes general productivity classification.

SUMMARY

1. *Selenastrum capricornutum* was introduced into autoclaved water collected from the euphotic layer of ten central Iowa lakes and incubated under set conditions. Each lake was visited three times, in the Spring of 1975, in the Fall of 1975, and in the Spring of 1976.

2. Secchi disk readings, specific conductance, alkalinity, free carbon dioxide, pH, ortho and metaphosphate and nitrate and nitrite nitrogen values were determined for each lake sample.

3. Alkalinity and specific conductance values were higher in those lakes located within the Wisconsin Glacial Drift.

4. Algal dry weights were correlated to the eutrophic status of each lake. All of the lakes studied can be considered mesotrophic with the exception of the two natural lakes which are eutrophic.

5. Changes in individual lake alkalinity between the Spring of 1975 and the Fall of 1975 also correlated to the eutrophic status of each lake with the same general results.

6. It is suggested that further studies on these lakes be more quantitative, employing more frequent samplings and including nutrient budgets and turnover to aid in developing a plan to improve water quality.

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APPENDICES

Table 8. Cell number (1 X 10^3 cells/ml) per flask per lake during the eight day incubation period, Spring, 1975.

Lake	Flask number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
1) Ahquabi	1	1.75	3.50	4.00	5.25	8.50	10.00	11.00	12.50
	2	2.10	4.50	5.00	7.00	9.00	10.50	12.00	12.00
	3	2.00	3.75	5.00	6.00	8.25	10.00	11.50	13.00
2) Ellis	4	2.00	3.75	5.00	7.00	10.00	12.00	11.50	12.00
	5	1.75	3.75	5.00	7.00	10.00	12.00	11.50	12.00
	6	1.75	3.25	5.00	6.50	8.50	10.00	12.00	12.00
3) Red Haw	7	1.50	2.75	4.00	6.00	7.25	8.00	9.00	9.25
	8	1.50	2.75	4.25	5.75	7.00	8.25	8.50	8.75
	9	1.50	3.00	4.50	5.50	7.00	8.25	8.25	8.25
4) Miami	10	2.50	4.00	5.00	8.00	9.25	12.00	12.25	12.00
	11	2.75	4.25	5.50	7.75	9.00	11.00	10.00	10.00
	12	2.00	3.50	5.00	7.50	8.50	10.00	10.50	10.00
5) Bob White	13	2.50	4.00	6.50	9.75	13.00	15.00	15.50	16.50
	14	2.00	4.50	7.00	10.50	12.50	16.00	15.50	16.00
	15	2.25	5.00	8.00	12.00	17.50	17.50	17.50	17.00

Table 8. Continued.

Lake	Flask number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
6) Briggs Woods	16	1.50	2.25	3.75	6.00	6.25	7.50	8.50	9.00
	17	1.80	3.25	4.25	5.50	7.50	8.50	9.00	9.00
	18	1.75	3.00	4.00	5.00	7.50	9.50	9.00	9.50
7) Badger	19	2.00	4.00	5.00	8.25	9.00	9.50	10.50	10.50
	20	2.00	3.50	4.75	7.25	10.50	11.50	12.50	12.00
	21	2.25	4.25	6.50	9.00	8.00	8.50	8.50	8.75
8) West Twin	22	1.50	2.50	4.50	6.75	9.00	10.00	11.25	11.50
	23	2.00	2.75	5.00	7.75	10.00	10.00	11.00	11.50
	24	1.75	2.50	6.25	5.00	8.00	10.50	10.50	10.50
9) Morse	25	2.75	5.75	10.00	16.50	24.25	26.00	27.25	27.00
	26	3.00	5.75	9.00	16.50	24.00	24.25	23.50	24.00
	27	2.50	4.00	9.00	16.50	25.00	26.00	26.75	27.25
10) Beeds	28	2.25	4.00	5.50	7.25	10.00	10.50	11.00	11.50
	29	1.75	3.00	5.00	7.00	10.00	10.50	11.00	10.00
	30	1.75	3.75	5.00	7.75	11.00	12.00	12.25	12.00

Table 9. Cell number (1 X 10^3 cells/ml) per flask per lake during the eight day incubation period, Fall, 1975.

Lake	Flask number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
1) Ahquabi	1	2.00	3.50	4.25	7.50	11.00	13.00	13.00	13.25
	2	2.00	3.00	4.75	8.00	12.00	14.00	12.50	13.00
	3	2.00	2.50	3.50	6.00	9.25	12.50	12.50	13.25
2) Ellis	4	1.50	3.00	2.75	6.50	10.00	12.00	12.50	13.25
	5	2.50	3.75	5.00	7.25	10.00	11.00	10.00	9.50
	6	1.50	2.00	4.25	5.00	7.50	8.75	11.00	11.00
3) Red Haw	7	2.00	3.00	4.75	7.50	8.50	9.50	9.50	9.50
	8	1.50	2.00	3.50	4.75	7.00	7.50	8.00	8.50
	9	1.50	3.25	5.50	6.00	7.00	7.50	8.00	8.00
4) Miami	10	1.50	2.75	4.50	4.50	8.00	9.00	10.00	10.50
	11	1.50	2.50	4.50	6.00	8.75	9.50	10.50	11.00
	12	1.50	2.25	4.00	6.75	7.75	9.00	11.00	11.00
5) Bob White	13	1.50	3.00	4.00	6.50	10.00	16.00	17.00	16.50
	14	2.00	4.00	7.50	8.00	12.00	15.50	17.00	17.00
	15	2.00	3.50	7.00	12.00	14.00	18.00	17.00	17.00

Table 9. Continued.

Lake	Flask number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
6) Briggs Woods	16	2.00	4.50	5.50	6.25	8.50	8.75	9.00	9.00
	17	2.00	5.50	6.00	6.75	8.00	8.25	8.00	8.50
	18	2.00	2.25	5.00	5.50	7.50	8.75	9.00	9.25
7) Badger	19	1.50	3.00	3.50	5.75	8.75	10.00	10.50	10.50
	20	1.75	3.50	5.00	5.50	6.50	8.75	10.00	10.50
	21	1.50	3.50	3.50	6.25	8.50	9.75	10.00	11.00
8) West Twin	22	1.50	1.75	4.25	10.00	18.00	19.50	21.00	21.50
	23	2.00	3.75	6.50	11.00	15.00	19.50	21.00	21.00
	24	2.50	5.00	7.50	12.50	19.50	21.50	21.00	21.50
9) Morse	25	2.50	4.75	8.75	16.00	24.25	29.50	30.00	30.25
	26	4.00	7.00	9.25	18.00	24.00	26.00	27.75	28.75
	27	4.25	7.75	13.00	19.50	25.50	27.50	28.75	28.00
10) Beeds	28	1.75	3.00	6.00	9.50	10.25	11.00	11.50	12.00
	29	1.75	4.25	6.00	10.00	11.25	12.00	11.00	12.25
	30	1.75	5.00	4.00	8.25	10.25	11.00	12.00	12.00

Table 10. Cell number (1×10^3 cells/ml) per flask per lake during the eight day incubation period, Spring, 1976.

Lake	Flask number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
1) Ahquabi	1	2.50	4.00	6.75	11.00	12.00	13.50	14.00	15.00
	2	2.25	3.75	5.00	9.75	14.00	15.00	14.00	15.50
	3	2.25	4.00	5.50	10.00	13.50	14.75	15.50	16.00
2) Ellis	4	1.75	2.75	3.75	8.00	12.50	13.00	13.00	13.25
	5	1.50	2.50	4.50	9.50	12.00	12.00	13.00	12.50
	6	2.25	3.00	6.25	9.00	11.00	12.50	14.00	13.00
3) Red Haw	7	2.00	4.25	7.00	8.25	8.50	9.00	9.00	10.00
	8	1.75	5.00	9.00	11.00	11.50	12.50	12.50	13.00
	9	1.50	3.00	4.75	6.75	8.00	9.50	9.50	9.50
4) Miami	10	1.75	2.50	4.50	5.50	8.50	9.00	9.50	9.50
	11	2.25	3.00	3.50	7.00	9.50	10.50	10.50	12.00
	12	2.00	3.00	3.00	6.75	10.50	8.00	9.00	8.00
5) Bob White	13	2.50	5.50	7.50	12.00	13.00	14.00	14.00	15.00
	14	2.25	2.00	5.75	9.00	11.00	12.00	14.75	15.00
	15	1.50	2.75	4.00	8.50	13.00	14.50	16.25	17.00

Table 10. Continued.

Lake	Flask number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
6) Briggs Woods	16	2.50	4.00	4.50	6.75	7.75	8.00	8.00	8.00
	17	2.25	4.25	5.00	6.50	8.50	8.25	8.25	8.25
	18	2.25	3.75	4.25	7.50	8.00	8.50	8.50	8.25
7) Badger	19	1.50	4.25	6.75	8.00	9.00	10.50	10.25	10.50
	20	2.00	2.75	3.75	6.00	7.00	8.75	10.25	10.25
	21	2.50	2.50	4.50	7.50	8.75	10.25	10.50	11.00
8) West Twin	22	2.75	7.50	13.00	19.50	21.00	22.50	22.50	23.00
	23	3.00	7.25	10.25	21.00	22.50	23.00	23.50	23.50
	24	2.25	4.50	8.75	9.50	17.50	22.00	21.00	21.00
9) Morse	25	4.00	8.25	15.00	24.25	29.00	33.00	33.50	34.00
	26	2.75	4.25	12.00	15.75	26.25	27.00	30.00	32.00
	27	2.50	5.00	11.25	24.00	27.50	29.50	31.50	31.50
10) Beeds	28	1.50	2.75	5.50	8.50	8.75	12.50	13.00	13.25
	29	2.75	4.75	8.50	9.00	10.50	13.00	12.00	12.25
	30	2.00	4.00	6.75	10.25	12.25	12.50	13.50	13.50